Middle East Journal of Applied Sciences
Volume: 15 | Issue: 01| Jan. – Mar. | 2025

EISSN: 2706 -7947 ISSN: 2077- 4613
DOI: 10.36632/mejas/2025.15.1.3
Journal homepage: www.curresweb.com
Pages: 33-45

Response of Fennel Plants (*Foeniculum vulgare* L.) and Soil Properties to Irrigation Intervals and Potassium Sources and Levels

Gihan A. Mohamed[1], Ghada F.H. El-Sheref[1] and A. G. M. Kenawy[2]

[1]Soil, Water and Environment Res., ARC, Giza, Egypt
[2]Medicinal and Aromatic Plants Res. Department, Horticulture Research Institute, ARC, Giza, Egypt

Received: 10 Dec. 2024 **Accepted:** 20 Jan. 2025 **Published:** 30 Jan. 2025

ABSTRACT

The experiment designed to study the effect of different irrigation intervals (every 21, 28 and 35 days) and potassium levels and sources (0.0,120 kg/fed feldspar, 240 kg/fed feldspar, 25kg /fed potassium sulphate and 50kg /fed potassium sulphate) on some soil properties , i.e., pH; EC; soil organic matter , particle density and N, P and K availability in soil after plant harvest as well as growth parameters, yield and its components ,essential oil and N, P and K concentration in fennel seeds and herbs . The experiment was conducted during two successive seasons of 2021/2022 and 2022/2023 at the Horticultural farm of Sids Agricultural Research Station, Beni-Suef Governorate, Egypt. The main results showed that increasing water intervals increased soil salinity, while soil available N and K in soil decreased after harvest as well as decreased all studied growth parameters, yield and its components, oil yield and N, P and K content in seeds and herbs, but it decreased oil percentage. Chemical or natural feldspar application improved organic matter and soil available K in soil after harvest, while feldspar only increased soil salinity. All studied quality and quantity of fennel plants were positively responded to potassium application. The differences between the effect of chemical and natural K- fertilizer on fennel quality and quantity is not significant. The results of the interaction indicate that highest values of quality and quantity of fennel plants are produced under irrigated the plants every 21 days and added high rate of K levels. Therefore, it could be recommended to applied K to fennel plants under moderately deficit water to obtain maximum yields.

Keywords: Fennel, feldspar, potassium, irrigation, soil properties and yield.

1. Introduction

In Egypt, fennel (*Foeniculum vulgare* L.) is the most important medicinal plant cultivated in it. It belonging to family Apiaceae, which consider the largest plant families in the world (about 450 genera and 3700 species). The members of this family are known as culinary, vegetables and medicine (Mozaffarian, 2007). Fennel is mainly grown in Middle Egypt, such as, Beni-Suef, Minia and Assuit Governorates. Fennel plant has erect stem and branches, about 1-2 m high, its leaf are 3-4 pinnately compound, its flowers has small five- pealed, its ambles are yellow, its fruit are oval (4-10 mm long) with strong smell and sweet taste (Ibrahaim, 2020). Fennel seeds contain essential oil, which used as flavoring materials in food making such as bread liqueur, pickles, cheese and pastries The seeds contain about 10.0% fat, 9.5% protein, 18.5 fiber, 13.4 % mineral, 42.3 % carbohydrates and about 0.7- 6.0 % volatile oil depending to genotype or the environmental conditions (Bhunic *et al.,* 2005). The essential oil in fennel seeds used in medicine as a stimulant, carminative, diuretic, galactagogic, sedative, expectorant, emmenagogic and antispasmotic. Moreover, it used to treat some diseases such as nervous disorder, cholera, constipation, bile disturbances, dysentery and diarrhoea. Also, it control some diseases affecting lug, chest, kidney, spleen and in colic pains (Zarshenas *et al.,* 2013).

In arid and semi arid water resources are scarce led to limiting plant production and land reclamation. In addition, Bisbis *et al.,* (2018) mentioned that environment stresses and /or climate

Corresponding Author: Gihan A. Mohamed, Soil, Water and Environment Res., ARC, Giza, Egypt.

changes negatively affected agricultural production and food supply. In Egypt climate changes compelled decision makers, scientists and the agronomists to think about water resources sustainability in future under the situation of water scareity, especially under the decreasing in water coming from Ethiopia and high rate of population (Quda, 2016). In general, the agricultural sector, in Egypt consumes about 80-90 % of total water resources, meanwhile under the limiting of water resources, the population in Egypt increased, which led to lower the per capita share of fresh water (Hafiz and Ewis, 2015). Consequently, there is need for decreasing of the consumption of water by plant through, plant breeding, increasing of the efficiency of irrigation methods, higher moisture depletion, longer irrigation intervals, skipping irrigation and especially early vegetative growth or during maturation stage (Tayel *et al.,* 2007). On the other hand, drought is the most environmental stress, which affects plant physiology, morphology and biochemistry, resulting in negative affects on crop production. In this concern, Esam *et al.,* (2021) reported that the effect of drought on many plants have been investigated less is known about its effect on aromatic plants, particularly on biosynthesis and accumulation.

Potassium is the most important macronutrient for plant growth and development. It is play an important function in activation more than sixty enzyme system. Potassium is necessary for cell division and cell elongation in young growing tissues. Also, it is very important in nutrients absorption and many physiological processes in plant (Marschner, 2012). Many investigators reported that K play an important role in water use efficiency, where it helps the plant to be tolerant for water deficit. Thomas and Thomas (2009) explained the role of K to increase plant tolerant for water stress by K inter into the guard cells around the stomata, the water accumulate in the cells, led to open the pores allowing gases to move out freely. In case of deficit water, K is pumped out from the guard cells, then the pores close tightly to minimize water loss and reduce the effect of drought stress. On the other hand, under K deficiency, the stomata become sluggish-slow to respond, consequently water lost. Moreover, Mengel and Kirkby (1987) stated that plant deficient in potassium is less able to uptake water resulted it more subjected to water stress.

The use of feldspar ($KAlSi_3O_8$) as natural potassium fertilizers (contain about 10% (K_2O) is low cost as alternative K- source (El- Sheref, 2012). Many authors reported the beneficial effect of natural potassium on crop production such as Hegazi *et al.,* (2014); Belal *et al.,* (2017); Abd El Wahab (2 020); and Mekawy and Abd El –Hafeez (2020).

The main purpose of this work were to evaluate: 1- The possibility to substituting partly or totally the expensive K- sulphate fertilizer by feldspar as cheap fertilizer, 2- The effect of irrigation intervals and K-levels on growth, productivity and water efficiency of fennel plants and 3- Improving the drought tolerance of fennel plants by using potassium, whether, chemical or natural fertilizer.

2. Materials and Methods

2.1. The experiment setup

Two field experiments were conducted on the experimental farm of the Horticultural Research Station, ARC, Beni-Suef Governorate, situated at latitude of 29° 24′ N, longitude 31° 04′ E with 30-40 m above the mean sea level in two successive seasons of 2012/2022 and 2022 /2023 to investigate the possibility of reducing the use of chemical K by using natural rock (feldspar) as well as eliminate the harmful effect of deficit water on fennel plants. The soil of the experiment was clay in texture, had pH of 8.0 and 8.1, EC of 1.22 and 1.47 (dSm^{-1}), organic matter of 1.5 and 1.6%, bulk density of 1.22 and 1.70 ($g\ cm^{-3}$), soil available water of 21.56 and 21.54 %, wilting point of 20.30 and 20.11 %, soil available N of 35.1 and 32.2 ugg^{-1}, soil available P of 15.7 and 17.1 ugg^{-1} and soil available K 196 and 202 ugg^{-1} in both seasons, respectively (according of A.O.A.C., 1995).

The total treatments were three irrigation intervals x Five potassium fertilization. The experiment included four replications and was designed in a split plot. Three different irrigation interval treatments were carried out in the main plots: irrigation every 15 (I_1), 28 (I_2), and 35 (I_3) days.

Five treatments of potassium application (K_1, K_2, K_3, K_4, and K_5) were included in the sub-plots as follows:

Main plot: Irrigation intervals

I_1: Irrigation every 21 days

I_2: Irrigation every 28 days
I_3: Irrigation every 35 days

Subplot: Potassium fertilization
K_0: 0.0 kg/fed
K_1: 50 % recommended rat of feldspar, 12kg K_2O/fed (about 120kg/fed feldspar)
K_2: 100 % recommended rat of feldspar, 24kg K_2O/fed (about 240kg/fed feldspar)
K_3: 50 % recommended rat of potassium sulphate, 12 kg K_2O/fed (about 25kg potassium sulphate /fed)
K_4: 100 % recommended rat of potassium sulphate, 24kg K_2O/fed (about 50kg potassium sulphate /fed), were located in sup plots.

Feldspar treatments were added before planting during land preparation, while chemical potassium sulphate treatments were added in two equal doses, the first after one month from planting and the second after one month later. Nitrogen fertilizer as ammonium nitrate (35.5 %N) at rate of 60kgN/fed was added on two equal doses, the first after one month after thinning and the other after one month later, while phosphorus fertilizer as superphosphate (15.5% P_2O_5) was added before planting, during land preparation.

2.2. Field experiment
The plot of the experiment was 3x3.5 m (10.5 cm^2=1/400 fed) containing 5 ridges, 3.5 m long and 0.6 m apart. Fennel seeds were received from Medicinal and Aromatic Plants Dep., ARC, Egypt and planted on 10 and 20 October in both seasons, respectively in hills at 0.4m apart on one side of ridges. The plants were thinned to two plants/hill after 30 days from sowing. All other agricultural practices for fennel production were done as in district.

2.3. Data recorded
At harvest, five plants were randomly taken to measure the following:
- Vegetative growth, i.e., plant height (cm), number of branches /plant, stem diameter (cm) and herb dry weight/ plant (g).
- Yield components (number of umbels /plant, number of umbellate/ umbel and 1000- seed weight (g).
- Yield measurements, i.e., herb yield / fed (kg), fruit yield/plant (g), fruit yield /fed (kg) and biological yield /fed (kg).
- Oil parameters, i.e., oil percentage, oil yield /plant (mL) and oil yield (L/fed).

2.4. Plant analysis
Also, plant samples were taken randomly from herbs and fruits to determine N,P and K according to A.O.A.C, (1995).

2.5. Soil analysis
Surface soil samples (0-30 cm) were taken from each plot to determine some soil properties (A.O.A.C., 1995).

2.6. Statistical analysis
The data were subjected to the statistical analysis as the method described by Snedecor and Cochran (1980). L.S.D at 5% level were used to compare between the treatments.

3. Results
3.1. Physical and chemical soil properties as well as its fertility
The data of the effect of irrigation intervals and potassium sources and levels on some soil properties and its fertility after fennel plants harvested are given in Tables 1 and 2. The data clearly show that irrigation intervals affected only soil salinity, and the availability of both N and K in soil. Increasing irrigation intervals led to significant increasing in soil EC values, while it reducing N and K availability in both seasons. The relative increasing in soil salinity due to increasing irrigation

intervals from 21 to 35 days reached to 8.3 and 4.8 % in both seasons, respectively. On the other hand, the decrement in soil available N and K resulted to increasing the irrigation intervals from 21 to 35 days reached to 17.8 and 9.3 % in the first season, respectively. The corresponding decrement in the second season were 18.8 and 12.7%, respectively.

As for the main effect of potassium application, the results indicate that soil organic matter and soil available K were affected by the levels of potassium application, where increasing K levels, whether chemical or natural fertilizers resulted in significant increasing in these traits. Moreover, soil organic matter did not respond to potassium sources, while soil salinity was significantly responded to K levels and sources of feldspar. Chemical K- fertilizer did not affect soil salinity in both seasons, while feldspar application positively increased soil salinity, especially at the high rate. In addition, it can be observed that natural fertilizer surpassed chemical fertilizer on its effect on soil available K after harvest. The soil properties and fertility did not respond to the interaction between irrigation intervals and potassium fertilization.

Table 1: Influence of irrigation intervals, potassium application and interactions on some soil properties of fennel plants under different levels and sources of potassium.

Treatments		pH		EC (dSm^{-1})		Organic matter (%)		Bulk density ($g\ cm^{-3}$)	
Irrigation	K-levels and sources	Season		Season		Season		Season	
		1st	2nd	1st	1st	2nd	1st	2nd	1st
I_1 21 days	K_0	8.02	8.14	1.19	1.39	1.46	1.62	1.23	1.21
	K_1	8.01	8.15	1.28	1.48	1.53	1.66	1.23	1.20
	K_2	8.02	8.14	1.32	1.52	1.55	1.69	1.22	1.20
	K_3	8.02	8.16	1.20	1.46	1.54	1.66	1.23	1.21
	K_4	8.01	8.13	1.22	1.45	1.56	1.70	1.22	1.21
Mean		**8.02**	**8.14**	**1.20**	**1.46**	**1.53**	**1.67**	**1.23**	**1.21**
I_2 28 days	K_0	8.00	8.13	1.21	1.42	1.49	1.63	1.22	1.21
	K_1	8.01	8.15	1.30	1.51	1.53	1.66	1.23	1.22
	K_2	8.01	8.14	1.35	1.55	1.56	1.68	1.22	1.22
	K_3	8.02	8.14	1.22	1.48	1.53	1.66	1.23	1.21
	K_4	8.01	8.13	1.24	1.48	1.56	1.69	1.22	1.22
Mean		**8.01**	**8.14**	**1.26**	**1.49**	**1.53**	**1.66**	**1.22**	**1.22**
I_3 35 days	K_0	8.01	8.14	1.26	1.49	1.46	1.62	1.23	1.22
	K_1	8.03	8.14	1.32	1.55	1.53	1.66	1.22	1.22
	K_2	8.01	8.13	1.39	1.59	1.56	1.69	1.22	1.21
	K_3	8.01	8.13	1.25	1.51	1.54	1.67	1.21	1.21
	K_4	8.02	8.13	1.26	1.53	1.56	1.69	1.22	1.22
Mean		**8.01**	**8.13**	**1.30**	**1.53**	**1.56**	**1.67**	**1.22**	**1.22**
Mean of K	K_0	8.01	8.14	1.22	1.43	1.56	1.62	1.23	1.21
	K_1	8.02	8.15	1.30	1.51	1.53	1.66	1.23	1.21
	K_2	8.01	8.13	1.35	1.55	1.56	1.69	1.22	1.21
	K_3	8.02	8.14	1.22	1.48	1.54	1.66	1.22	1.21
	K_4	8.01	8.13	1.24	1.49	1.56	1.69	1.22	1.22
L.S.D at 0.05									
Irrigation intervals		N.S	N.S	0.02	0.02	N.S	N.S	N.S	N.S
Potassium Fertilization		N.S	N.S	0.05	0.07	0.02	0.03	N.S	N.S
Irrigation x Potassium		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

K_0: 0.0 kg/fed.; **K_2:** 120 kg/fed feldspar**;** **K_2:** 240 kg/fed feldspar**;** **K_3:** 25 kg/fed K-sulphate**;** **K4:**50 kg/fed K-sulphate

Table 2: Influence of irrigation intervals, potassium application and interactions on soil fertility of fennel plants under different levels and sources of potassium.

Treatments		Soil available N (ppm)		Soil available P (ppm)		Soil available K (ppm)	
Irrigation	K-levels and sources	Season		Season		Season	
		1st	2nd	1st	1st	2nd	1st
I1 21 days	K0	35.6	32.4	15.1	17.4	181	195
	K1	35.2	31.8	15.2	17.1	211	225
	K2	35.4	32.0	15.0	16.9	220	240
	K3	35.1	31.5	15.4	17.3	203	216
	K4	35.6	32.2	15.3	17.0	211	226
Mean		**35.4**	**32.0**	**15.2**	**17.2**	**205**	**220**
I2 28 days	K0	31.6	29.4	15.2	17.2	178	180
	K1	30.9	29.0	15.4	17.7	195	203
	K2	31.2	28.6	15.0	16.9	211	229
	K3	32.4	28.1	15.6	17.3	187	285
	K4	31.7	29.1	15.5	17.5	199	207
Mean		**31.9**	**28.9**	**15.3**	**17.5**	**194**	**201**
I3 35 days	K0	29.2	26.2	15.3	17.1	170	168
	K1	29.6	26.5	15.4	17.5	190	197
	K2	28.9	25.4	15.1	17.3	202	219
	K3	29.7	26.0	15.7	16.8	181	176
	K4	28.0	25.9	15.3	17.0	189	200
Mean		**29.1**	**26.0**	**15.4**	**17.2**	**186**	**192**
Mean of K	K0	31.1	29.3	15.2	17.2	176	181
	K1	31.9	29.1	15.3	17.4	199	208
	K2	31.8	28.7	15.0	17.0	211	229
	K3	32.4	28.5	15.6	17.1	190	192
	K4	31.8	29.1	15.4	17.2	200	211
L.S.D at 0.05							
Irrigation intervals		1.02	0.93	N.S	N.S	4.56	4.83
Potassium Fertilization		N.S	N.S	N.S	N.S	6.02	6.55
Irrigation x Potassium		N.S	N.S	N.S	N.S	N.S	N.S

K0: 0.0 kg/fed.; **K2:** 120 kg/fed feldspar**; K2:** 240 kg/fed feldspar**; K3:** 25 kg/fed K-sulphate**; K4:**50 kg/fed K-sulphate

3.2. Growth parameters

Regarding to irrigation intervals, the data in Table 3 reveal that watered fennel plants every 21 days produced the highest values of vegetative growth (plant height, number of branches /plant and stem diameter). The relative increment in these parameters due to irrigated every 21 days reached to about 7.3, 14.8 and 8.9% when compared to irrigated every 35 days in the first season, respectively. The corresponding increasing in the second season were 7.6, 15.4 and 8.7 % in the same order.

The present data clearly show that the studied growth characters were positively responded to potassium levels, whether in chemical or natural sources. Increasing K levels resulted in significant increases in fennel vegetative growth. Comparing with control, added the high rate of feldspar or potassium sulphate increased plant height, number of branches/plant and stem diameter by about 10.2 and 11.8, 14.4 and 16.1, and 21.9 and 26.3% in the first season, respectively. Similar trends were obtained in the second season. It is worthy to notice that the difference between natural and chemical K sources on vegetative growth did not reach to the significant values.

The data of the interaction between irrigation and potassium treatments indicate that added high level of feldspar or potassium sulphate mitigate the drought harmful, where the plants received high K level under irrigated every 28 days exhibited growth parameters, statistically equal to that supplied with full irrigation.

Table 3: Influence of irrigation intervals, potassium application and interactions on vegetative growth of fennel plants under different levels and sources of potassium.

Treatments		Plant height (cm)		No of branches/plant		Stem diameter (cm)	
Irrigation	K-levels and sources	Season		Season		Season	
		1st	2nd	1st	1st	2nd	1st
I1 21 days	K0	160.8	164.1	7.33	7.56	1.63	1.68
	K1	166.9	170.2	7.89	8.00	1.95	1.99
	K2	170.9	175.0	8.44	8.55	1.96	2.01
	K3	167.0	171.6	8.33	8.56	1.97	2.01
	K4	173.1	177.2	8.56	8.78	2.08	2.06
Mean		**167.7**	**171.6**	**8.11**	**8.29**	**1.92**	**1.95**
I2 28 days	K0	151.6	156.8	7.22	7.33	1.62	1.68
	K1	157.0	162.2	7.78	7.82	1.80	1.85
	K2	167.2	173.4	8.41	8.54	2.00	1.96
	K3	166.6	170.0	8.11	8.22	1.91	1.98
	K4	169.7	173.9	8.56	8.75	2.11	2.03
Mean		**162.4**	**167.2**	**8.02**	**8.13**	**1.89**	**1.90**
I3 35 days	K0	144.7	145.2	6.44	6.55	1.56	1.59
	K1	151.0	154.3	6.78	6.89	1.72	1.75
	K2	162.6	166.5	7.22	7.33	1.88	1.90
	K3	154.2	157.2	6.80	6.91	1.74	1.77
	K4	165.1	168.0	7.30	7.36	1.87	1.91
Mean		**155.5**	**158.6**	**6.91**	**7.01**	**1.75**	**1.78**
Mean of K	K0	152.4	156.0	7.01	7.15	1.60	1.65
	K1	159.3	162.2	7.48	7.57	1.82	1.86
	K2	167.9	171.6	8.02	8.14	1.95	1.96
	K3	163.6	166.2	7.75	7.90	1.87	1.92
	K4	170.3	173.0	8.14	8.30	2.02	2.00
L.S.D at 0.05							
Irrigation intervals		2.9	3.0	0.05	0.07	0.04	0.04
Potassium Fertilization		4.7	5.0	0.07	0.08	0.04	0.05
Irrigation x Potassium		6.3	6.7	0.11	0.13	0.07	0.08

K0: 0.0 kg/fed.; **K2:** 120 kg/fed feldspar**;** **K2:** 240 kg/fed feldspar**; K3:** 25 kg/fed K-sulphate**; K4:**50 kg/fed K-sulphate

3.3. Yield and its components

The data in **Tables 4 and 5** represent the yield components (No of umbles/plant, No of ambllules/ umble and 1000 fruit weight) and yield measurements i.e., herb dry weight/plant, herb dry weight /fed, fruit yield/plant, fruit yield /fed and biological yield /fed as affected by irrigation and potassium treatments. As for the main effect of irrigation, the data indicate that increasing the irrigation intervals resulted in significantly reduction in all studied yield and its components parameters for fennel plants in both seasons. The relative decrement in these parameters due to increased irrigation intervals from 21 to 35 days in the first season reached to 16.61, 21.32, 40.77, 20.02, 20.04,15.68,17.35 and 16.06%, respectively. Same trends were obtained in the second seasons.

Concerning the main effect of potassium, the data show that potassium application whether natural or chemical sources had positive effects on all studied yield and yield components parameters. It is worthy to notice that yield and its components were significantly increased as the level of natural or chemical fertilizers increased. Moreover, the results reveal that the effectiveness of the two potassium fertilizer sources did not statistically differ.

Regarding the effect of the interaction, the data reveal that these parameters were responded the interaction between the two factors. The fennel plants received high rate of potassium fertilizers under irrigated every 28 days produced yield and yield component parameters, statistically equal to those

watered with full irrigation. In general, the highest values of these parameters were achieved from the treatments of irrigation every 21 or 28 days and supplied with 240kg/fed feldspar or 50kg potassium sulphate. On the other hand, the plants without potassium application when irrigated every 35 days recorded the lowest values.

3.4. Essential oil

The data given in Table 6 represent the response of essential oil in fennel seeds expressed as oil percentage as well as oil yield/plant and oil yield /fed to irrigation intervals and potassium application and their interaction. As for the main effect of irrigation, the results reveal that seed oil percentage increased as the irrigation intervals increased. Irrigation every 21, 28 and 35 days yielded 1.37, 1.40 and 1.43% oil in fennel seeds, respectively in the first season. The corresponding oil percentages in the second season were 1.34, 1.35 and 1.42 %. However increasing irrigation intervals decreased both oil yield /plant or fed. The decrement in oil yield/plant or per fed. due to increasing irrigation intervals from 21 to 38 days reached to 12.35 and 13.35% in the first season, respectively. Similar trends were obtained in the second season.

Table 4: Influence of irrigation intervals, potassium application and interactions on yield components of fennel plants under different levels and sources of potassium.

Treatments		No of umbels /plant		No of umbellate /umbel		1000-fruit weight (g)	
Irrigation	K-levels and sources	Season		Season		Season	
		1st	2nd	1st	1st	2nd	1st
I1 21 days	K0	30.00	35.33	45.22	48.13	8.68	8.12
	K1	40.33	42.67	61.29	66.01	12.09	12.01
	K2	44.00	45.00	67.35	70.22	14.33	14.07
	K3	41.33	43.33	62.34	66.36	12.26	12.18
	K4	45.67	46.08	68.01	72.22	14.70	14.61
Mean		**40.27**	**42.48**	**60.84**	**64.59**	**12.41**	**12.20**
I2 28 days	K0	25.10	30.67	37.02	39.86	6.18	5.98
	K1	38.90	40.16	51.17	54.40	10.12	10.11
	K2	43.91	44.96	68.38	70.05	14.05	13.89
	K3	41.25	41.66	52.01	56.00	10.39	10.13
	K4	45.52	45.92	69.16	72.03	14.16	13.82
Mean		**38.94**	**40.67**	**55.55**	**58.47**	**10.98**	**10.79**
I3 35 days	K0	21.57	24.57	31.12	33.29	4.69	4.66
	K1	33.43	35.90	46.20	47.51	5.54	5.50
	K2	38.90	41.00	56.51	58.20	10.28	9.16
	K3	34.87	36.00	47.71	48.34	5.72	5.62
	K4	39.13	42.10	57.82	59.02	10.51	9.28
Mean		**33.58**	**35.91**	**47.87**	**49.27**	**7.35**	**6.84**
Mean of K	K0	25.56	30.19	37.79	40.43	6.62	6.25
	K1	37.55	39.58	52.89	55.97	9.25	9.21
	K2	42.27	43.65	64.08	66.16	12.89	12.36
	K3	39.15	40.13	54.02	56.90	9.46	9.31
	K4	43.44	44.70	65.00	67.76	13.12	12.57
L.S.D at 0.05							
Irrigation intervals		1.29	1.31	2.16	2.33	1.01	1.00
Potassium Fertilization		1.66	1.70	2.80	2.97	0.86	0.85
Irrigation x Potassium		2.02	2.28	3.14	3.54	1.36	1.25

K0: 0.0 kg/fed.; **K2:** 120 kg/fed feldspar**;** **K2:** 240 kg/fed feldspar**;** **K3:** 25 kg/fed K-sulphate**;** **K4:**50 kg/fed K-sulphate

Table 5: Influence of irrigation intervals, potassium application and interactions on fennel yields of fennel plants under different levels and sources of potassium.

Treatments		Herb d.w./plant (g)		Herb d.w./fed (kg)		Fruit yield/ plant (g)		Fruit yield/ fed (kg)		Biological yield /fed (kg)	
Irrigation	**K-levels and sources**	**Season**		**Season**		**Season**		**Season**		**Season**	
		1st	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**
I1 21 days	**K0**	181.1	182.5	5331.0	5462.9	39.33	43.36	1162.1	1207.7	6493.1	6670.6
	K1	210.2	210.2	6281.5	6291.3	59.57	62.10	1765.3	1862.1	8046.8	8153.4
	K2	218.9	220.6	6447.3	6552.5	67.33	70.00	2100.6	1952.3	8547.9	8504.8
	K3	212.1	213.1	6296.6	6325.1	60.16	63.82	1786.2	1871.8	6475.4	8196.9
	K4	219.0	222.0	6456.1	6572.6	68.25	70.15	2114.2	1965.1	8579.4	8695.9
Mean		**208.3**	**209.7**	**6162.5**	**6240.9**	**58.93**	**62.09**	**1785.7**	**1771.8**	**7628.5**	**8044.3**
I2 28 days	**K0**	172.2	180.2	5101.3	5213.4	34.23	39.43	1021.1	1161.6	6122.4	6375.0
	K1	205.6	206.3	5321.5	5426.1	57.10	60.43	1701.4	1792.5	7114.0	7218.6
	K2	216.8	219.5	6386.8	6421.6	66.40	68.67	1981.3	1900.3	8368.1	8372.6
	K3	206.8	207.0	5391.7	5442.5	58.06	62.11	1710.6	1800.3	7102.3	7342.8
	K4	218.0	223.5	6401.3	6452.3	66.82	69.31	1986.5	1918.5	8387.8	8645.6
Mean		**203.9**	**207.3**	**5720.5**	**5791.2**	**56.52**	**59.99**	**1680.2**	**1714.6**	**7418.9**	**7590.9**
I3 35 days	**K0**	124.4	130.0	3702.2	3776.3	30.67	33.41	916.6	1002.1	4618.8	4778.5
	K1	172.0	176.6	5033.5	5120.1	46.90	51.21	1396.1	1521.3	6429.6	6641.4
	K2	180.9	189.2	5415.7	5503.2	61.03	62.03	1825.5	1802.1	7241.2	7305.3
	K3	173.1	178.4	5070.6	5141.6	47.53	52.30	1399.7	1532.4	6470.3	6674.0
	K4	182.5	190.4	5414.6	5511.9	62.33	62.16	1841.2	1816.2	7255.8	7328.1
Mean		**166.6**	**172.9**	**4927.3**	**5010.6**	**49.69**	**52.22**	**1475.8**	**1534.8**	**6403.1**	**6545.5**
Mean of K	**K0**	159.2	164.23	4711.50	4817.53	34.74	38.73	1033.27	1238.0	5744.77	5941.37
	K1	195.9	197.70	5545.50	5612.50	54.52	57.91	1620.93	1725.3	7196.80	7337.80
	K2	205.5	209.77	6083.27	6159.10	64.92	66.90	1969.13	1884.9	8052.40	8060.90
	K3	197.3	199.50	5586.30	5636.40	55.25	59.41	1632.17	1734.8	6682.67	7404.57
	K4	206.5	211.97	6090.67	6178.93	65.80	67.21	1980.63	1900.0	8074.33	8223.20
L.S.D at 0.05											
Irrigation intervals		3.4	2.7	25.6	25.0	1.03	1.21	15.5	16.3	22.9	24.5
Potassium Fertilization		4.8	4.1	29.1	28.6	1.22	1.35	19.8	20.5	26.1	28.7
Irrigation x Potassium		5.5	5.3	32.3	32.1	1.85	2.02	23.6	25.1	30.3	32.1

K0: 0.0 kg/fed.; **K2:** 120 kg/fed feldspar**; K2:** 240 kg/fed feldspar**; K3:** 25 kg/fed K-sulphate**; K4:**50 kg/fed K-sulphate

Considering the main effect of potassium application, the data show that oil percentage and yields were positively affected by potassium application. Added 240 kg feldspar /fed or 50kg potassium sulphate /fed increased oil percentage, oil yield /plant or oil yield /fed by about 4.41 and 4.41; 95.74 and 97.87; and 98.22 and 99.79% over control in the first season, respectively. Similar increment was obtained in the second season. It can be observed that the effect of the two studied potassium sources on oil percentage or oil yield were increased as its level increased. Moreover, the difference between the effect of natural potassium and chemical sources on the essential seed oil were not significant in both seasons.

The data of the interaction reveal that oil yields were affected by the interaction between irrigation and potassium treatments, while oil percentage did not affect. Application of potassium, whether in natural or chemical sources for fennel plants irrigated every 28 days produced seed oil yield /plant or per fed. statistically equal to those supplied with full irrigation.

Table 6: Influence of irrigation intervals, potassium application and interactions on oil percent and yield of fennel plants under different levels and sources of potassium.

Treatments		Oil percent (%)		Oil yield/plant (mL)		Oil yield/fed (L)	
Irrigation	K-levels and sources	Season		Season		Season	
		1st	2nd	1st	1st	2nd	1st
I1 21 days	K0	1.33	1.30	0.52	0.56	15.46	15.70
	K1	1.37	1.33	0.82	0.83	24.18	24.77
	K2	1.39	1.36	0.94	0.95	29.20	26.55
	K3	1.37	1.34	0.82	0.86	24.47	25.08
	K4	1.38	1.38	0.94	0.97	29.18	29.30
Mean		**1.37**	**1.34**	**0.81**	**0.83**	**24.50**	**24.28**
I2 28 days	K0	1.36	1.32	0.47	0.52	13.89	15.33
	K1	1.39	1.37	0.79	0.83	23.65	24.56
	K2	1.41	1.35	0.94	0.93	27.94	26.34
	K3	1.40	1.38	0.81	0.86	23.95	24.84
	K4	1.42	1.35	0.95	0.94	28.21	29.61
Mean		**1.40**	**1.35**	**0.79**	**0.82**	**23.53**	**24.14**
I3 35 days	K0	1.40	1.38	0.43	0.46	12.83	13.83
	K1	1.43	1.41	0.67	0.72	19.96	21.45
	K2	1.45	1.44	0.88	0.89	26.47	25.95
	K3	1.43	1.41	0.68	0.74	20.02	21.61
	K4	1.46	1.45	0.91	0.90	26.88	26.33
Mean		**1.43**	**1.42**	**0.71**	**0.74**	**21.23**	**21.83**
Mean of K	K0	1.36	1.33	0.47	0.51	14.06	14.95
	K1	1.40	1.37	0.76	0.79	22.60	23.59
	K2	1.42	1.38	0.92	0.92	27.87	26.28
	K3	1.40	1.38	0.77	0.82	22.81	23.84
	K4	1.42	1.39	0.93	0.94	28.09	28.41
L.S.D at 0.05							
Irrigation intervals		0.02	0.03	0.02	0.02	0.51	0.44
Potassium Fertilization		0.02	0.02	0.03	0.04	0.62	0.59
Irrigation x Potassium		N.S	N.S	0.05	0.05	1.12	1.36

K0: 0.0 kg/fed.; **K2:** 120 kg/fed feldspar**;** **K2:** 240 kg/fed feldspar**;** **K3:** 25 kg/fed K-sulphate**;** **K4:**50 kg/fed K-sulphate

3.5. Nutrient status in fennel seeds and herbs

Data in Table 7 represent the effect of irrigation intervals and potassium application on N, P and K concentration in fennel seeds and herbs. The data clearly show that increasing the amount of applied water led to significant increasing in N, P and K in seeds and herbs. Fennel plants irrigated every 21 days contain 2.75, 0.33, 2.40% N, P and K in its seeds in first season, and 1.54, 0.33 and 2.22% in its herbs. While, the plants watered every 35 days contain 2.43, 0.23 and 2.25% respectively in its seeds and 1.42, 0.28 and 2.16% its herb in the abovementioned respect. Similar trends were obtained in the second season.

As for potassium application, the results indicate that plants supplied with natural feldspar or chemical form contain highest values of N, P and K in seeds and herbs. Statistically, added natural-K yielded N, P and K in fennel seeds or herbs equal to due to chemical form. Also, it can notice that the effectiveness of K- fertilizers on nutrient content was more pronounced as increasing K-levels.

The data of the interaction show that, the nutrient content in fennel seeds or herbs did not respond to the interaction between irrigation and potassium application. In general the highest values of in N, P and K in seeds and herbs were obtained from the treatment of irrigated every 21 days and fertilized with 240 kg feldspar/ fed or 50 kg potassium sulphate. On the other hand, the lowest values of N, P and K in fennel plants were achieved for the plants under water stress with no potassium application.

Table 7: Influence of irrigation intervals, potassium application and interactions on N, P and K concentration on fennel plants under different levels and sources of potassium.

Treatments Irrigation	K-levels and sources	N (%)				P (%)				K (%)			
		Seed season		Herb season		Seed season		Herb season		Seed season		Herb season	
		1st	2nd	1st	2nd	1st	1st	2nd	1st	2nd	1st	1st	2nd
I1 21 days	K0	2.55	2.41	1.43	1.40	0.26	0.24	0.27	0.27	2.31	2.29	2.16	2.14
	K1	2.67	2.56	1.48	1.46	0.31	0.30	0.33	0.30	2.39	2.36	2.21	2.19
	K2	2.89	2.77	1.62	1.58	0.37	0.35	0.36	0.34	2.44	2.42	2.25	2.23
	K3	2.70	2.59	1.51	1.48	0.33	0.31	0.34	0.30	2.40	2.37	2.21	2.20
	K4	2.93	2.78	1.64	1.67	0.39	0.37	0.37	0.35	2.46	2.43	2.26	2.24
Mean			**2.62**	**1.54**	**1.52**	**0.33**	**0.31**	**0.33**	**0.31**	**2.40**	**2.37**	**2.22**	**2.20**
I2 28 days	K0	2.31	2.27	1.39	1.36	0.22	0.20	0.24	0.23	2.26	2.24	2.13	2.11
	K1	2.59	2.40	1.44	1.41	0.27	0.26	0.29	0.27	2.29	2.27	2.18	2.16
	K2	2.72	2.56	1.50	1.46	0.31	0.30	0.34	0.30	2.35	2.34	2.22	2.20
	K3	2.62	2.44	1.46	1.42	0.29	0.27	0.31	0.28	2.29	2.28	2.19	2.17
	K4	2.78	2.59	1.53	1.54	0.33	0.31	0.35	0.31	2.36	2.35	2.23	2.20
Mean			**2.45**	**1.46**	**1.44**	**0.28**	**0.27**	**0.31**	**0.28**	**2.31**	**2.30**	**2.19**	**2.17**
I3 35 days	K0	2.01	1.92	1.37	1.34	0.18	0.16	0.21	0.20	2.15	2.13	2.10	2.08
	K1	2.35	2.18	1.39	1.38	0.21	0.20	0.27	0.26	2.23	2.21	2.16	2.13
	K2	2.68	2.50	1.45	1.42	0.25	0.24	0.30	0.29	2.30	2.29	2.19	2.18
	K3	2.39	2.21	1.41	1.39	0.22	0.22	0.28	0.27	2.25	2.23	2.17	2.13
	K4	2.71	2.55	1.47	1.44	0.27	0.25	0.32	0.31	2.31	2.30	2.20	2.19
Mean			**2.27**	**1.42**	**1.39**	**0.23**	**0.21**	**0.28**	**0.27**	**2.25**	**2.23**	**2.16**	**2.14**
Mean of K	K0	2.29	2.20	1.40	1.37	0.22	0.20	0.24	0.23	2.24	2.22	2.13	2.11
	K1	2.54	2.38	1.44	1.42	0.26	0.25	0.30	0.28	2.30	2.28	2.18	2.16
	K2	2.76	2.61	1.52	1.49	0.31	0.30	0.33	0.31	2.35	2.35	2.22	2.20
	K3	2.57	2.41	1.46	1.43	0.28	0.27	0.31	0.28	2.31	2.29	2.19	2.17
	K4	2.81	2.64	1.55	1.55	0.33	0.31	0.35	0.32	2.38	2.36	2.23	2.21
L.S.D at 0.05													
Irrigation intervals		0.05	0.04	0.03	0.03	0.02	0.01	0.01	0.01	0.04	0.05	0.03	0.02
Potassium Fertilization		0.08	0.06	0.03	0.02	0.02	0.02	0.01	0.02	0.05	0.04	0.03	0.03
Irrigation x Potassium		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

K0: 0.0 kg/fed.; **K2:** 120 kg/fed feldspar**; K2:** 240 kg/fed feldspar**; K3:** 25 kg/fed K-sulphate**; K4:**50 kg/fed K-sulphate

4. Discussion

In arid and semi-arid regions, the irrigation water is the limiting factor for crop production and land reclamation. The problem of water stress is expected to increase further due to the expansion of population, fast decline of water and the economic activity in most areas satiated in arid and semi-arid regions. Therefor, it must be adopt most suitable irrigation strategies, which resulted in optimum yield and save irrigation water. On the other hand, potassium is an important nutrient for plant production, but use high amounts of it resulted in increases the cost of agricultural production. In this concern, natural K-fertilization may be a good alternative cheaper source to chemical K- fertilizer.

Results from this investigation showed that increasing the amount of applied water led to significant decreasing in soil salinity and significant reduction in soil available nitrogen and potassium in post harvest soil, while pH, organic matter, bulk density and soil available phosphorus did not affect. The promotive effect of irrigation water on soil salinity is mainly due to the enhancement of leaching efficiency by increasing applied water. In contrast, increasing irrigation water increased N and K availability which may be due to improved root growth and soil microorganisms activity, consequently increased the residual soluble N and K.

Also, our results indicated that increasing irrigation intervals from 21 to 35 days resulted in significant decreasing in all studied fennel growth, yield and yield components, oil yield and nutrient content in fennel seeds and herbs. In contrast, oil percentage increased as increasing irrigation intervals. The negative effect of increasing irrigation intervals on fennel productivity may be attributed to the deficit moisture conditions shortened the period needed to reach the maximum values of photosynthetic parameters (Parmoon *et al.,* 2019). Also, Diaz-Lopez (2012) stated that under

drought stress, the nutrients flow to roots becomes limited, consequently reduced nutrient uptake. In addition, Parmon *et al.,* (2019) mentioned that water deficiency may caused intensify abortion of flower and seed, thus resulted in ultimately lower fennel seed yield. These results agree with the results obtained by many investigators such as, Ali *et al.,* (2020), Arolkar *et al.,* (2021) and Shivran *et al.,* (2023). The enhancement of oil percentage caused by water stress may be due to the reduction in irrigation water especially during translocation of sugar from leaves to seeds resulted in increased in oil percentage (El- Sammanody *et al.,* 2010). Also, Parmoon *et al.* (2019) stated that the draught condition caused a dramatic reduction in plant biomass, hence the oil percentage increased when compared to seed weight. These resulted are in harmony to obtained by Emami *et al.* (2017) who stated that oil percentage in fennel seeds increased under severe stress conditions.

Potassium is the most important nutrient for increased crop production, where use of chemical K-fertilizer at high rate increased the crop production cost as well as its environmental pollution. The good alternative cheaper source of chemical potassium is the natural K- rock. Our current study reveal that soil organic matter and soil available K after fennel plants harvest increased due to chemical or natural K, while soil salinity affected only by natural rock K application. The beneficial effect of potassium on soil organic matter and potassium availability may be due to the positive effect of K on roots and vegetative growth of plant, in turn during its decomposition added potassium and organic matter to soil. On the other hand, soil salinity responded only to feldspar application, where increasing feldspar levels led to significant increasing in soil salinity. The slow solubility of feldspar may be consider a good explanation for its effect on soil salinity (Abou-el- Seoud, 2012). Similar results were obtained by Sarhan and Abd-El-Gayed (2017); Mekawy and Abd El-Hafeez (2020); Arolkar *et al.,* (2021) who reported that potassium application increased potassium availability.

Potassium fertilization in form chemical or natural rock resulting in markedly increasing in growth parameters, yield and its components, essential oil and N, P and K concentration. The effectiveness of K application increased as increasing its level. Also, it can be notice that, the effect of feldspar on these traits are similar to those due to potassium sulphate. The pronouncing effect of potassium on fennel productivity parameters is mainly due to the well known function of K in plant growth and development as mentioned in the introduction. These results are similar to these obtained by Younis *et al.* (2021), Hafiz and Ewis (2015), Ali *et al.* (2020) and Arolkar *et al.* (2021). Who found a positive effect of potassium on quality and quantity of fennel plants.

The data of the interaction between irrigation intervals and potassium levels and sources indicated that added high rate of potassium can eliminate the negative effect of water stress. The fennel productivity parameters under irrigated every 28 days when fertilized with 50kg potassium sulphate /fed or 240 kg feldspar/ fed were statistically equal to those received full water. The stimulatory of K to reduce the drought stress hazards may be attributed to the important function of K on water in plants, where it helps the plant to tolerant for water deficiency. Thomas and Thomas (2009) explain this mechanism by K regulate the closing and opening of stomata, photosynthesis, nutrient and water transport as well as plant cooling are depended on stomata. The guard cell of stomata accumulate water and swell when K moves into it, resulting in open the pores, which allowing gases to move and out. Under deficit water, K is pumped out of the guard cell, consequently pores tightly close to keep water from losing. These results are in harmony with the results of many authors such as Said and Hussein (2010), Sary and Elsokkary (2019) and Ali *et al.* (2020).

5. Conclusion

In view of the study main findings and the data collected over two successive seasons, it may be possible to reach the conclusion that, in Middle Egypt's clay soil, watering fennel plants every 28 days and adding 240 kg of feldspar or 50 kg of fed potassium sulphate was the most effective treatment. This produced fennel plants of the highest quality and quantity compared to those that were irrigated every 21 days, as well as improved soil organic matter and K availability in the soil after harvest. This indicates that fennel plants might be grown in drought-stressed conditions if they were fertilized with potassium.

References

Mekawy, A.Y. and A.M. Abd El Hafeez, 2020. Reducing the amount of mineral phosphorus and potassium fertilizers by using its natural sources for Red Globe grapevines. Journal Applied Horticulture, 22(2):110-116.

Abd-El Wahab, M.M., 2020. Enhancement of wheat grain nutritional value using some nano materials. M.Sc. Faculty of Post graduate Studies for Advanced Sciences (PSAS). Beni-Suef University (BSU). Egypt.

Abou-el-Seoud, B. and A. Abdel-Megeed, 2012. Impact of rock materials and biofertilization on P and K availability for maize (*Zea maize*) under calcareous soil condition, Saudi J. Bio. Sci., 19(1): 55-63.

Ali, H.A.N. and M.S. Abu-hashim, 2020. Potential effect of irrigation intervals and potassium phthalate on fennel plants grown in semi-arid regions. Egypt. J. Soil. Sci., 60(1): 83-98.

Arolkar, N.M., P.K. Nagre, S.P. Deokar, K.D. Wakulkar and A.M. Jadhav, 2021. Effect of different levels of nitrogen and potassium on soil nutrient status of fennel seed production. Int. Journal of chemical studies, 9 (1): 1860-1862.

A.O.A.C., 1995. Association of Official Agricultural Chemists. Official Methods of Analysis 14th Ed. A.O.A.C., Washington, D.C.U.S.A.490-510.

Belal, B.E.A., M.A. El-Kenawy and T.S.A. Abo EL-Wafa, 2017. Partial replacement on mineral potassium fertilizer for Thompson Seed less grapevines by using different sources of organic and natural fertilizers. Plants Production, Mansoura Univ., 8(1): 19-25.

Bhunia, S.R., R.P.S. Chauhan and B.S. Yadaw, 2005. Effect nitrogen and irrigation on water use, moisture extraction, nutrient uptake and yield of fennel (*Foeniculum vulgar* Mill). Indian Journal of Agronomy, 50(1):73-76.

Bisbis, M.B., N. Gruda and M. Blank, 2018. Potential impacts of climate on vegetable production and product quality -A review. J. Clean. Prod., 170: 1602- 1620.

Diaz -Lopez, L., V. Gimeno, I. Simon, V. Martinez, W.M. Rodriguez-Ortega and F. Garcia, 2012. Jatropha cureas seeding show a water conservation strategy under drought conditions based on decreasing leaf growth and stomatal conductance, Agric. Water Manag., 105:(48-56).

El- Sammanody, M.K.M., S.M. El-Marsafawy and H.K.A. Rehab, 2010. Impact of dificit irrigation at different growth stages on some sesame varieties in upper Egypt J. of Plant Production, 1(17):857-871.

El-Sheref, G.F.H., 2012. Minimizing pollution with inorganic fertilizers through some nutritional techniques. Ph.D. Thesis, Fac. of Agric., Moshtoher, Bnha Univ., Egypt.

Emami Bistgani, Z., S.A. Siadat, A. Bakhshandeh, A.G. Pirbalouti and M. Hashemi, 2017. Interactive effect of drought stress and chitosan application on Physiological characteristics and essential oil yield of Thymus daenensis Celak , Crop J., 5 (5): 407-415.

Esam, A.A.A. and M.R.R. Khater, 2021. Effect of irrigation intervals and sodium selenite on growth, seed yield and essential oil of fennel. Middle East J. Agric. Res., 10 (1): 391-399.

Hafiz, Y.A.M. and M.M. Ewis, 2015. Effect of irrigation regime and potassium fertilizer rates on growth, yiled , oil composition and some water relations of fennel plants (*Foeniculum vulgare* Mill) under middle Egypt conditions. Bull. Fac. Agric., Cairo Univ., 66:142-155.

Hegazi, A.H., N.R. Samra, E.A. Hassan and A.M. Yasmin, 2014. Effect of compost as organic fertilizer, natural rocks and some different biofertilizers on yield and quality of Flame Seedless grapevines. J. Plant Production, Mansoura Univ., 5(10): 1625-1636.

Ibrahim, I.A.Y., 2020. Impact of different nitrogen forms on fennel plants (*Foeniculum vulgare* L.) grown on newly reclaimed soil. Ph.D. Thesis, Fac. of Agric. Benha Univ., Egypt.

Marschner, P., 2012. Marschner s Mineral Nutrition of Higher Plants, 3rd ed.; Academic Press : London , UK, 178- 189.

Mengel, K. and E.A. Kirkby, 1987. Principles of Plant Nutrition 4th Edition. International Potash Institute, IPI, Bern , Switzerland, 685.

Mekaway, A.Y. and A.M. Abd-El-Hafeez, 2020. Reducing the amount of mineral phosphorus and potassium fertilizers by using its natural sources for Red Globe grapevines. J. of Applied Horticulture, 22 (2): 110-116.

Mozaffarian, V., 2007. Umbelliferae, In: Flora of Iran, No. 54. (Assadi M, Khatamsaz M, Maasoumi AA, eds) Research Institute of Forests and Rangelands, Tehran .596.

Parmoon, Gh., A. Ebadi, S. Jahanbkhsh and M. Hashemi, 2019. Physiological response of fennel (*Foeniculum vulgare* Mill.) to drought stress and plant growth regulators. Russian J. of Plant Physiology, 66 (5): 795- 805.

Quda, S., 2016. Major crops and water scarcity in Egypt: irrigation water management under changing climate. springer: Cham, Switzerland, ISBN 978- 3-319-21771-0.

Said-Al Ahl, H.A.H. and M.S. Hussein, 2010. Effect of water stress and potassium humate on the productivity of organo plant using saline and fresh water irrigation. Ozean. J. Ap. Sci., 1:125-141.

Sarhan, M.G.R. and S.Sh. Abd-El- Gayed, 2017. The possibility of using feldspar as alternative potassium for cotton fertilization combined with silicate dissolving bacteria, humic acids and farmyard manure and its effect on soil properties. J. Soil Sci. and Agric. Eng., Mansoura Univ., 8(12): 761-767.

Sary, D. and I. Elsokkary, 2019. Effect of irrigation water regime in persence of organic or biological fertilizer on olive trees. Egypt J. Soil Sci., 59(1): 67-85.

Snedecor, G.W. and W.G. CochraN, 1980. Statistical Method 18thEd. Lowa State Univ., Press, Ames, Lowa, U.S.A.

Shivran, A.C., B.L. Dudwal, G.K. Mittal, G. L. Kumawate, R. Manohar and R.L. Mandeewal, 2023. Effect of irrigation management on growth, yield, water use efficiency and economics of fennel (*Foeniculum Vulgare* Mill). Agric Mechanization in Asi., 54 (3): 12467- 12475.

Tayel, M.Y., A.M. El-Gindy, M. El-Hady and H.A. Ghany, 2007. Effect of irrigation system on: yield, water and fertilizer use efficiency of grape. Appli. Sci. Res., 3 (5): 367-372.

Thomas, T.C. and A.C. Thomas, 2009. Vital role of potassium in the osmotic mechanism of stomata aperture modulation and its link with potassium deficiency. Plant Signal Behaviour , 4(3) : 240-243.

Younis, S.I., N.M. Rashedorcid and E.A. Moursi, 2010. Effect of water stress and potassium fertilizer on growth, yield and composition of essential oil fennel plant. J. Plant Production, Mansoura Univ., 1 (7): 931-946.

Zarshenas, M.M., A. Arabzadeh, T.M. Ajdari, G. Kordafshari, A. Zargaran and A. Mohagheghzadeh, 2013. Application of herbal exudates in traditional Persian medicine. Galen. Med. J., 1(2): 78-83.